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(71) Applicant: **International Business Machines Corporation**
Old Orchard Road
Armonk, N.Y. 10504 (US)

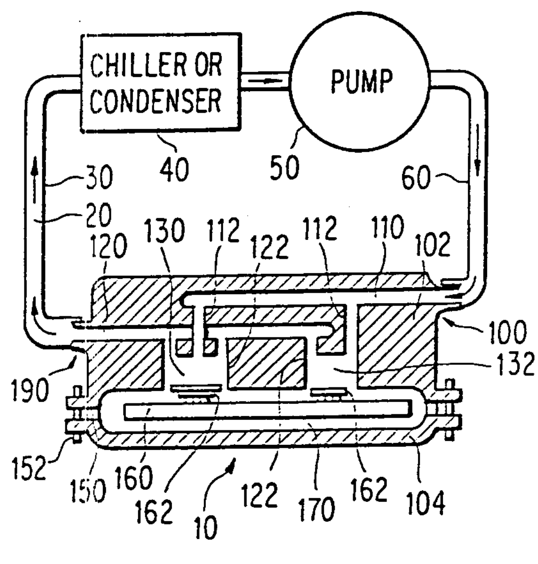
(72) Inventor: **Messina, Gaetano**
929 Rt. 82
Hopewell Junction, New York 12533 (US)

(74) Representative: **Colas, Alain**
Compagnie IBM France Département de Propriété Intellectuelle
F-06610 La Gaude (FR)

(54) Integral cooling system for cooling electronic components.

(57) An integral cooling system (10) for cooling a plurality of electronic components (162), including: a cooling fluid manifold (102) for mounting over the plurality of electronic components; a main fluid inflow duct (110) within the manifold for supplying pumped cooling fluid; a main fluid outflow duct (120) within the manifold for removing pumped cooling fluid; for each respective electronic component of the plurality of electronic components (162): a component cooling chamber (130, 132) within the manifold, for application of cooling fluid to an area immediately adjacent the electronic component; a fluid supplying duct (112) within the manifold to supply cooling fluid from the main fluid inflow (110) duct to the chamber; and, a fluid removing duct (122) within the manifold to remove cooling fluid from the chamber to the main fluid outflow duct (120). In preferred embodiments, there is a thermally-conductive slug or piston disposed between the respective electronic component and component cooling chamber to prevent direct application of a flow of the pumped cooling fluid to the respective electronic component, and to encourage uniform cooling across the respective electronic component. A seal can be provided between the manifold and slug or piston to maintain the cooling fluid within the cooling chamber and prevent the cooling fluid from directly contacting the respective electronic component.

FIG. 1



Jouve, 18, rue Saint-Denis, 75001 PARIS

The subject invention is directed to an integral cooling system for cooling electronic components.

Numerous cooling systems for cooling electronic components are known in the art. Known systems which include a hat' type of arrangement and/or intermediary thermal conduction components between a cooling medium and an electronic component to be cooled, include:

Kawamoto (US-A-No. 3,908,188)

Hosono, et al. (US-A-No. 3,989,099)

Chu et al. (US-A-No. 3,993,123; assigned to the same assignee, IBM, as the present application)

Flint et al. (US-A-No. 4,759,403; assigned to the same assignee, IBM, as the present application)

Chu et al. (US-A-No. 4,765,400; assigned to the same assignee, IBM, as the present application)

E.G. Loeffel, S.W. Nutter and A.W. Rzant, IBM Technical Disclosure Bulletin, Vol. 20, No. 2, July 1977, "Liquid Cooled Module With Compliant Membrane", p. 673-674

V.W. Antonetti, H.E. Liberman and R.E. Simons, IBM Technical Disclosure Bulletin, Vol. 20, No. 11A, April 1978, "Integrated Module Heat Exchanger"

P. Hwang, S. Oktay, A.L. Pascuzzo and A.C. Wong, IBM Technical Disclosure Bulletin, Vol. 20, No. 11A, April 1978, "Conduction Cooling Module", p. 4334-4335

C. J. Keller and K.P. Moran, IBM Technical Disclosure Bulletin, Vol. 21, No. 6, November 1978, "High-Power Rectifier Jet-Cooled Heat Sink", p. 2438

C.D. Ostergren, IBM Technical Disclosure Bulletin, Vol 27, No. 1B, June 1984, "Mini Conformal Cold Plate", p. 494-495

The above and other systems including a "hat" arrangement and/or intermediary thermal conduction components are disadvantageous in that thermal resistance of the system is increased and thermal transfer efficiency decreased.

Known systems which include complex "bellows" types of arrangements, and/or complex arrangements of discrete assembled parts, include:

Meeker et al. (US-A-No. 4,138,692; assigned to the same assignee, IBM, as the present application)

Ono (US-A-No. 4,688,147)

Mittal (US-A-No. 4,750,086)

Yamamoto et al. (US-A-No. 4,783,721)

Nicol et al. (US-A-No. 4,791,983)

Tustaniwskyj et al. (US-A-No. 4,809,134)

Yamamoto et al. (European Patent No. 0 151 546 A2)

D. Balderes and J.R. Lynch, IBM Technical Disclosure Bulletin, Vol. 20, No. 11A, April 1978, "Liquid Cooling of A Multichip Module Package", p. 4336-4337

V. W. Antonetti, R.C. Chu, K.P. Moran and R.E. Simons, IBM Technical Disclosure Bulletin, Vol. 21, No. 6, November 1978, "Compliant Cold Plate Cooling Scheme", p. 2431

G.T. Galyon and P. Singh, IBM Technical Disclosure Bulletin, Vol. 28, No. 11, April 1986, "New TCM Design Using Bellows", p. 4759

The above and other systems including complex bellows' types of arrangements, and/or complex arrangements of discrete assembled parts are disadvantageous in that both manufacturing complexity and cost are increased, and alignment problems are prevalent.

Further known approaches include:

Wiegand (US-A-No. 2,917,685)

Butler et al. (US-A-No. 3,365,620; assigned to the same assignee, IBM, as the present application)

Melan et al. (US-A-No. 3,414,775; assigned to the same assignee, IBM, as the present application)

Barkan (US-A-No. 3,991,396)

Cutchaw (US-A-No. 4,381,032)

Murphy et al. (US-A-No. 4,777,561)

M.E. Ecker, IBM Technical Disclosure Bulletin, Vol. 10, No. 7, December 1967, "Interface for Thermal Exchange Devices", p. 943

J.H. Seely, IBM Technical Disclosure Bulletin, Vol. 11, No. 7, December 1968, "Combination Cooling System", p. 838-839

K.S. Sachar, IBM Technical Disclosure Bulletin, Vol. 20, No. 9, February 1978, "Liquid Jet Cooling of Integrated Circuit Chips", p. 3727-3728

A.H. Johnson, IBM Technical Disclosure Bulletin, Vol. 20, No. 10, March 1978, "Device Cooling", p. 3919

J.C. Eid and M.L. Zumbrunnen, IBM Technical Disclosure Bulletin, Vol. 29, No. 12, May 1987, "Circuit Module With Evaporative Cooling From Sintered Coating On Pistons", p. 5195-5196

Edmund L. Andrews, Business Technology, "For Chips That Overheat: A Tiny Radiator" (New York Times, Wednesday, September 20, 1989)

Any "essential material' not contained in the present disclosure, but contained in any above- or below-cited U.S. patents or allowed U.S. patent applications, is incorporated herein by reference. Any "non-essential material" not contained in the present disclosure, but contained in any above- or below-cited U.S., foreign or regional patent publications, prior-filed, commonly-owned U.S. applications, or non-patent publications, is incorporated herein by reference.

With the advent of ever increasing computation speeds of computers, VLSI (Very Large Scale Integration) circuit densities have increased proportionately to satisfy demand in the market place. However, increased VLSI circuit densities and chip densities increase power dissipation requirements to enormous levels. For example, typical current semiconductor chip programs are expected to require power dissipation capability in excess of 70 watts. Estimates for future semiconductor chip programs reach 90-100 watts. The increase in chip power is taking place without any increase in chip area, and in fact, it is expected that chip areas will be decreased slightly due to recent developments in VLSI technologies. All of the above developments are necessary to enhance computer machine computational speeds, but place very aggressive design requirements on electronic component cooling schemes.

Air cooling is no longer a viable method for satisfying such high power dissipation requirements. Further, none of the approaches disclosed in the above-mentioned references can provide high power dissipation, while at the same time being low in manufacturing cost and complexity, and provide accurate and easy alignment to respective discrete electronic components which are to be cooled.

SUMMARY OF THE INVENTION

The present invention is directed toward addressing the foregoing deficiencies in the art by providing a cooling system high in power dissipation, low in manufacturing cost and complexity, and providing accurate and easy alignment to electronic components to be cooled.

All of the above objectives are accomplished by an integral cooling system for cooling a plurality of electronic components, the system comprising: a cooling fluid manifold for mounting over the plurality of electronic components; a main fluid inflow duct within the manifold for supplying pumped cooling fluid; a main fluid outflow duct within the manifold for removing pumped cooling fluid; for each respective electronic component of the plurality of electronic components: a component cooling chamber within the manifold, for application of cooling fluid to an area immediately adjacent the electronic component; a fluid supplying duct within the manifold to supply cooling fluid from the main fluid inflow duct to the chamber; and, a fluid removing duct within the manifold to remove cooling fluid from the chamber to the main fluid outflow duct.

In a preferred embodiment, there is a thermally-conductive slug disposed between the respective electronic component and component cooling chamber to prevent direct application of a flow of the pumped cooling fluid to the respective electronic component, and to encourage uniform cooling across the respective electronic component. A seal can be provided between the manifold and slug to maintain the cooling fluid within the cooling chamber and prevent the cooling fluid from directly contacting the respective electronic component. Further, the slug can comprise one of a star-shaped and grooved pattern to encourage a predetermined flow of the cooling'fluid across the slug.

In another preferred embodiment, the slug is replaced with a piston within the cooling chamber, which is biased to maintain contact between the piston and respective electronic component.

The slug or piston can each have at least one of a predetermined thickness and predetermined material conductivity property to provide a :predetermined power dissipation capability.

In a direct cooling embodiment, the fluid supplying duct comprises a duct portion for directing a flow of the pumped cooling fluid into direct contact with the respective electronic component.

A plurality of component cooling chambers are arranged along respective lengths of the main fluid inflow duct and main fluid outflow duct, and respective fluid supplying ducts and fluid removing ducts are arranged such that cooling fluid is supplied in parallel to the component cooling chambers, and the pumping pressure resistance across the main fluid inflow and outflow ducts is maintained low.

In another preferred embodiment, the main fluid inflow duct and main fluid outflow duct each have a longitudinal cross-section which is one of tapered or stepped, increasing in cross-section in a direction in which the main fluid inflow duct or main fluid outflow duct is required to carry cumulative volumes of cooling fluid from component cooling chambers along the main fluid inflow and outflow ducts.

At least one of the main fluid inflow duct, main fluid outflow duct, component cooling chamber, fluid supplying duct and fluid removing duct comprises a flow control arrangement for defining a volume of cooling fluid applied to the electronic components.

Finally, in a preferred embodiment, the manifold is substantially a metallic one-piece manifold, made of a substantially homogenous material, in which at least one of a casting, drilling, milling, planing and etching operation has been used to define main fluid inflow ducts, main fluid outflow ducts, component cooling chambers, fluid supplying ducts, and fluid removing ducts.

FIG. 1 is a partial schematic, partial cutaway view of an integral cooling system according to the present invention.

FIG. 2 is a partial cutaway view of the cooling fluid manifold of the present invention.

FIG. 3 is a further partial cutaway view of the cooling fluid manifold of the present invention.

FIG. 4 is a partial top view taken along a line 4-4′ of the cooling fluid manifold of FIG. 3.

FIG. 5 is another partial cutaway view of the cooling fluid manifold of the present invention, illustrating a variety of possible component cooling chamber arrangements.

FIGS. 6a and 6b are top views illustrating possible groove pattern arrangements for a top of a slug or piston.

FIG. 7 is a partial cutaway view of the cooling fluid manifold of the present invention, and having stepped main fluid inflow and outflow ducts.

FIG. 8 is a partial cutaway view of the cooling fluid manifold of the present invention, and having tapered main fluid inflow and outflow ducts.

Throughout the several drawings, like components will be designated with like reference numerals, and redundant discussion of the same will be omitted.

Turning now to a detailed description of the preferred embodiments of the invention, in FIG. 1, a substrate or printed circuit board 160 contains electronic components 162 which require intense power dissipation in the range of 75 watts to 120+ watts. Such intense power dissipation requirements cannot be satisfied using air-cooling arrangements, but instead are satisfied using the present unique and novel fluid cooling arrangement.

More particularly, FIG. 1 is a partial schematic, partial cutaway view of an integral cooling system 10 of the present invention. A cooling fluid 20 is pumped and circulated through a cooling fluid circuit consisting of an outflow return tube 30, chiller or condenser 40, pump 50, inflow supply tube 60, and cooling fluid manifold 102, 104. The outflow return tube 30, chiller or condenser 40, pump 50 and inflow supply tube 60 can each be constructed of any of numerous arrangements well known in the art, and are not further discussed as such components are not part of the inventive subject matter of the present invention. Although not illustrated, further well known fluid circuit components can also be incorporated, e.g., filters, and ion exchanger, expansion tanks, etc.

Turning now to a more detailed description of the cooling fluid manifold 102, 104 of the present invention, cooling fluid 20 within the inflow supply tube 60 is introduced into the cooling fluid manifold at single or plural input ports 100. The cooling fluid 20 travels through single or plural main fluid inflow ducts 110 within the manifold for supplying pumped cooling fluid along a longitudinal length of the manifold, and then through fluid supplying ducts 112 within the manifold to supply cooling fluid from the main fluid inflow duct 110 to component cooling chambers 130, 132.

Fluid removing ducts 122 within the manifold remove cooling fluid from the chambers 130, 132 to single or plural main fluid outflow ducts 120. The cooling fluid 20 within the main fluid outflow ducts 120 is removed from the manifold using single or plural output ports 190.

FIG. 2 is enlarged, cross-sectional view of the manifold 102, and which is more illustrative of an alternative cooling fluid flow through the manifold 102 wherein a main cooling inflow 21 and outflow 22 have opposing general directions (c.f., FIG. 1's main inflow and outflow have the same general direction). One caveat is in order with respect to FIG. 2 (and FIGS. 5, 7 and 8 discussed below), i.e., FIG 2 (and FIGS. 5, 7 and 8) does not exactly correspond to a side view of the manifold illustrated in FIGS. 3 and 4, but is instead, a modified cutaway view meant to be illustrative of a parallel inflow and outflow of cooling fluid to a row of chambers disposed along longitudinal lengths of respective main fluid inflow and outflow ducts 110, 120.

More particularly, a main inflow 21 of a cooling fluid 20 is illustrated as dividing into subflows entering the fluid supplying ducts 112 to provide cooling fluid in parallel to at least three chambers 130. After traveling through the component cooling chambers 130, the cooling fluid traveling in parallel through the fluid removing ducts 122 recombines into main outflow 22. Such parallel supplying and removing of cooling fluid to chambers disposed in a row along longitudinal lengths of respective main fluid inflow and outflow ducts 110, 120, is advantageous in that pumping pressure resistance across corresponding pairs of main fluid inflow and outflow ducts is maintained low. Further, as the cooling chambers along a row are fluid supplied in parallel rather than in series, a cumulative or increasing level of heat typical along a series fluid circuit is avoided, and there is a more even distribution of cooling fluid across the manifold. Further, a clog or malfunction within the local fluid circuit of any respective chamber will not effect fluid supply to remaining chambers along the row, and accordingly, electronic components cooled by the remaining chambers may not be thermally damaged.

FIG. 3 is an enlarged, cross-sectional end view of the manifold 102, which is more illustrative of three parallel rows 301-303 of component cooling chambers, with each row having its own main fluid inflow and outflow ducts 110, 120. FIG. 3 is further illustrative of one possible arrangement wherein a single main fluid inflow duct 110 is provided for each row and at an upper portion of the manifold 102, and wherein dual main fluid outflow ducts 120 are provided for each row at an intermediate portion of the manifold.

FIG. 4 is a partial top view taken along a line 4-4′ of the cooling fluid manifold of FIG. 3, and is even more illustrative of the three parallel rows 301-303 of component cooling chambers. FIG. 4 is further illustrative of an embodiment wherein an input port 101 is disposed on the same side of the manifold 102 as output ports 190, resulting in FIG. 2's alternative cooling fluid flow through the manifold 102 wherein a main cooling inflow 21 and outflow 22 have opposing general directions. If the FIG. 4's embodiment is instead provided with an input port 100 (indicated by the dashed line in FIG. 4) disposed on a side opposite from output ports 190, the result will be FIG. 1's cooling fluid flow with main inflow and outflow having the same general direction. Accordingly, it can be seen that the direction of cooling fluid inflow and outflow can be dictated by the placement of the input/output ports.

One of the important aspects of the present invention, which allows the present invention to provide intense (i.e., 75 watt -120+ watt) power dissipation, is the ability to provide, for each respective electronic component (of a plurality of electronic components), a component cooling chamber 130 within the manifold, for application of cooling fluid to an area immediately adjacent the electronic component. The present invention offers a variety of thermal conduction arrangements which can be disposed between the component cooling chamber 130 and the electronic component to be cooled. More particularly, FIG. 5 is partial cutaway view of the cooling fluid manifold of the present invention, illustrating a variety of possible component cooling chamber arrangements.

In the preferred arrangement illustrated with respect to the FIG. 5's left-most component cooling chamber, a thermally-conductive slug or thin metallic disk 510 is disposed as an intermediary between the component cooling chamber and the electronic component 512 which is to be cooled. Such preferred arrangement provides advantages in at least two regards. First, the thermally-conductive slug prevents direct application of a flow of the pumped cooling fluid onto the respective electronic component, thus avoiding erosion of the same. Second, such thermally-conductive slug acts to encourage uniform cooling across the respective electronic component. In a preferred embodiment, a dimensional thickness of the slug should be maintained very thin (e.g., 0.5 mm) in order to minimize thermal resistance introduced by the slug. The slug may be further spring-loaded, using a spring 514, into biased contact with the electronic component in order to enhance and guarantee the slug/component interface.

In a second arrangement illustrated with respect to the FIG. 5's second left-most component cooling chamber, a thermally-conductive piston 520 is disposed as an intermediary between the component cooling chamber and the electronic component 522 which is to be cooled. Such piston also provides the advantage of preventing direct application of a flow of the pumped cooling fluid onto the respective electronic component, and provides a further advantage wherein the piston is movable over a wide distance range into and out of the component cooling chamber, thus allowing the piston vertically to adapt to electronic components disposed at a variety of heights above the substrate. Such piston arrangement is somewhat disadvantageous, in that the thicker piston (as compared to the preferred thin slug) represents a large thermal resistance which decreases the thermal efficiency of the energy transfer between the electronic component and the cooling fluid. The piston may likewise be spring-loaded, using a spring 524, into biased contact with the electronic component in order to enhance and guarantee the piston/component interface.

Both the slug and piston arrangements can be used to provide customized cooling to each electronic component. More particularly, a power dissipation capability provided to an electronic component can be customized by inclusion/omission of a slug/piston (omission providing direct, unprotected cooling as discussed ahead) and/or variation of the slugs/pistons thickness or material conductivity property. Such variations afford construction of intermediary thermal components having a wide range of thermal resistances, which, in turn, allow such customized power dissipation.

FIGS. 6a and 6b are top views illustrating possible groove pattern or passage arrangements for the top of a slug or piston which groove arrangements can be used to encourage a predetermined flow of the cooling fluid across (or through) the slug or piston. More particularly, FIG. 6a illustrates a parallel groove type of arrangement 610, while FIG. 6b illustrates a star-shaped groove or passage arrangement 620. The ability to dictate groove arrangements and encourage predetermined flow patterns is important in that uniform cooling and heat transfer can be more accurately controlled. The aforementioned Yamamoto et al. (U.S. Patent 4,783,721) reference contains further teachings regarding groove arrangements.

The slug and piston arrangement can further be customized to represent a sealed arrangement, or a leaky arrangement. More particularly, if water or any other type of corrosive/electrically-conductive cooling fluid is used, it is necessary to isolate the electrical components from direct contact with such cooling fluid. Such is accomplished by providing some type of seal between the manifold 102 and the slug or piston. Examples of practical seals include an O-ring, silicon, weld, etc. If the slug or piston arrangement is a leaky one purposefully allowing cooling fluid contact with the electrical components, then the cooling fluid should be a non-corrosive and electrically non-conductive fluid, e.g., fluorocarbon.

FIG. 5's third, left-most component cooling chamber is an example of a totally unsealed and unprotective arrangement, wherein pumped cooling fluid 530 is pumped directly onto an electrical component 532. Such arrangement without any protective slug or other intermediary component, represents the most thermally efficient arrangement as there is no intermediary component adding thermal resistance to degrade the component/cooling fluid heat transfer.

If a leaky slug, leaky piston or unsealed arrangement is utilized, then further provision must be made to contain the cooling fluid to an enclosed area containing the electrical components to be cooled. FIG. 1, having a leaky slug arrangement with respect to a left component cooling chamber, and an unsealed arrangement with respect to a right chamber, is illustrative of an exemplary suitable arrangement wherein the substrate 160 is maintained between cooling fluid manifold halves 102, 104 and in a contained bath of cooling fluid 170. A seal 150 (e.g., an O-ring) maintains the fluid seal, while fastening devices 152 maintain the halves in a mutually fixed relation.

Returning to FIG. 5, a right-most component cooling chamber is illustrative of a sealed, yet terrain-adaptable arrangement wherein a flexible, yet thermally-conductive layer 540 is allowed to conform to, and maintain contact with, an irregularly shaped electronic component 542 (e.g., a resistor or capacitor). The aforementioned M.E. Ecker, , Vol. 10, No. 7, December 1967, "Interface for Thermal Exchange Devices", p. 943, and D. Balderes and J.R. Lynch, IBM Technical Disclosure Bulletin, Vol. 20, No. 11A, April 1978, "Liquid Cooling of A Multichip Module Package", p. 4336-4337 references contain teachings regarding suitable flexible thermal interfaces.

In order to further increase the efficiency of cooling fluid flow, maintain an equal pressure along the main fluid inflow and outflow ducts, and avoid any dead (i.e., non-circulating) areas within the body of cooling fluid, the main fluid inflow duct and main fluid outflow duct can each have a longitudinal cross-section which is tapered or stepped, increasing in cross-section in a direction in which the main fluid inflow duct or main fluid outflow duct is required to carry cumulative volumes of cooling fluid to or from component cooling chambers along the main fluid inflow and outflow ducts. FIG. 7 is a partial cutaway view of the cooling fluid manifold 702 having stepped main fluid inflow 710 and outflow 720 ducts. FIG. 8 is a partial cutaway view of the cooling fluid manifold 802 having tapered main fluid inflow 810 and outflow 820 ducts.

Several further approaches are available for customizing and controlling cooling fluid flow through the manifold 102. More particularly, as a first approach, the number or cross-sectional size of the fluid supplying ducts 112 and/or fluid removing ducts 122 can be varied to control the volume of cooling fluid flowing through a component cooling chamber. As examples, see the right-most chamber 132 illustrated in FIGS. 1 and 8, both of which illustrate component cooling chambers having only a single fluid supplying duct 812 and a single fluid removing duct 822 (as opposed to the dual fluid removing ducts illustrated throughout the remainder of the FIGS), resulting in a lesser volume of cooling fluid flowing through the chamber 132 and applied to the corresponding electronic component. As a second approach, standard manifolds can be constructed which allow maximum anticipated possible cooling fluid flow (i.e., as staple items), and the standard manifold can be modified utilizing, for example, inserts 501 (FIGS. 4 and 5) placed within the main fluid inflow and outflow ducts 110, 120, the component cooling chamber 130, fluid supplying duct 112 and fluid removing duct 122 to restrict a cross-section, and control a volume of cooling fluid flow through the same and ultimately applied to the electronic components. Further, the cross-sectional areas of the outflow return tube 30, inflow supply tube 60 or other fluid circuit components (e.g., a variable-flow valve) coupling to the input and output ports 100, 190 can also be used to control such flow.

In a preferred embodiment, the manifold is substantially a metallic one-piece manifold, made of a substantially homogenous material, and at least one of a casting, drilling, milling, planing and etching operation is used to define the main fluid inflow ducts, main fluid outflow ducts, component cooling chambers, fluid supplying ducts and fluid removing ducts. Plastic is a less preferred material for the manifold.

Claims

1. An integral cooling system for cooling a plurality of electronic components, said system comprising:

a cooling fluid manifold for mounting over said plurality of electronic components;

main fluid inflow duct within said manifold for supplying cooling fluid;

main fluid outflow duct within said manifold for removing cooling fluid;

for each respective electronic component of said plurality of electronic components:

a component cooling chamber within said manifold, for application of cooling fluid to an area immediately adjacent said electronic component;

a fluid supplying duct within said manifold to supply cooling fluid from said main fluid inflow duct to said chamber; and,

a fluid removing duct within said manifold to remove cooling fluid from said chamber to said main fluid outflow duct.

2. A system as claimed in Claim 1, further comprising:

a thermally-conductive slug disposed between said respective electronic component and said component cooling chamber to prevent direct application of a flow of said cooling fluid to said respective electronic component, and to encourage uniform cooling across said respective electronic component.

3. A system as claimed in Claim 1, further comprising:

a piston within said cooling chamber, said piston being biased to maintain contact between said piston and said respective electronic component, to prevent direct application of a flow of said cooling fluid to said respective electronic component, and to encourage uniform cooling across said respective electronic component.

4. A system as claimed in Claim 3, further comprising:

a seal between said manifold and slug or piston to maintain said cooling fluid within said cooling chamber and prevent said cooling fluid from directly contacting said respective electronic component.

5. A system as claimed in Claim 2, 3 or 4:
wherein said slug or piston has at least one of a predetermined thickness and predetermined material conductivity property to provide a predetermined power dissipation capability.

6. A system as claimed in Claim 2, 3 or 4:
wherein said slug or piston comprises one of a starshaped and grooved pattern to encourage a predetermined flow of said cooling fluid across said piston.

7. A system according to any one of the preceding Claims:
wherein said fluid supplying duct comprises a duct portion for directing a flow of said cooling fluid into direct contact with said respective electronic component.

8. A system according to any one of the preceding Claims:
wherein a plurality of said component cooling chambers are arranged along respective lengths of said main fluid inflow duct and main fluid outflow duct, and respective said fluid supplying ducts and said fluid removing ducts are arranged such that cooling fluid is supplied in parallel to said component cooling chambers, and a pumping pressure resistance across said main fluid inflow and outflow ducts is maintained low.

9. A system as claimed in Claim 8:
wherein said main fluid inflow duct and main fluid outflow duct each have a longitudinal cross-section which is one of tapered or stepped, increasing in cross-section in a direction in which said main fluid inflow duct and main fluid outflow duct is required to carry cumulative volumes of cooling fluid from component cooling chambers along said main fluid inflow and outflow ducts.

10. A system according to any one of the preceding Claims:
wherein at least one of said main fluid inflow duct, said main fluid outflow duct, said component cooling chamber, fluid supplying duct, fluid removing duct comprises a flow control arrangement for defining a volume of cooling fluid applied to said electronic components.

11. A system according to any one of the preceding Claims:
wherein said manifold is substantially a metallic one-piece manifold, made of a substantially homogenous material, in which at least one of a casting, drilling, milling, planing and etching operation has been used to define said main fluid inflow ducts, said main fluid outflow ducts, said component cooling chambers, fluid supplying ducts, and fluid removing ducts.

12. A system according to any one of the preceding Claims, further comprising:
at least one of water and a liquid fluorocarbon as said cooling fluid;
a pump for pumping said cooling fluid; and,
at least one of a chiller and condenser for cooling said cooling fluid.

13. An integral cooling system for a chip, comprising:
a chamber;
a slug or piston having a cooling surface facing said chamber, and a contact surface for contact with said chip;
a fluid inlet opening into said chamber for supplying a cooling fluid thereto; and,
at least one outlet for carrying said fluid away from said chamber.

FIG. 4

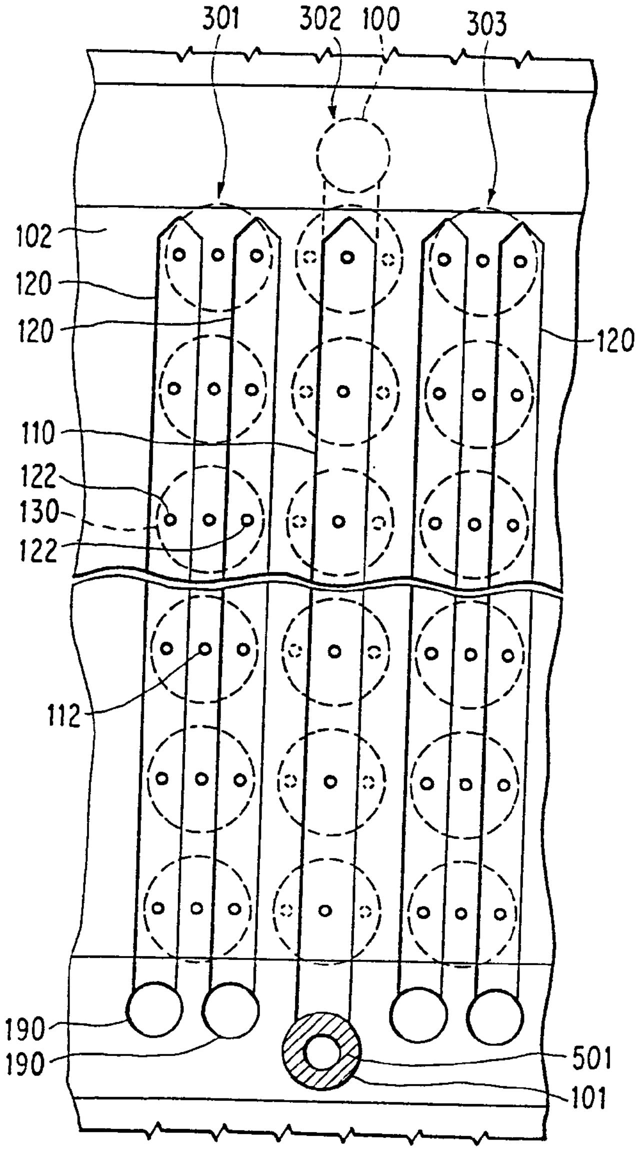


FIG. 1

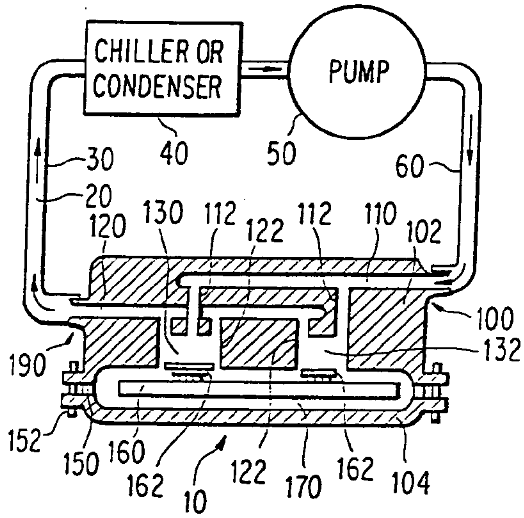


FIG. 2

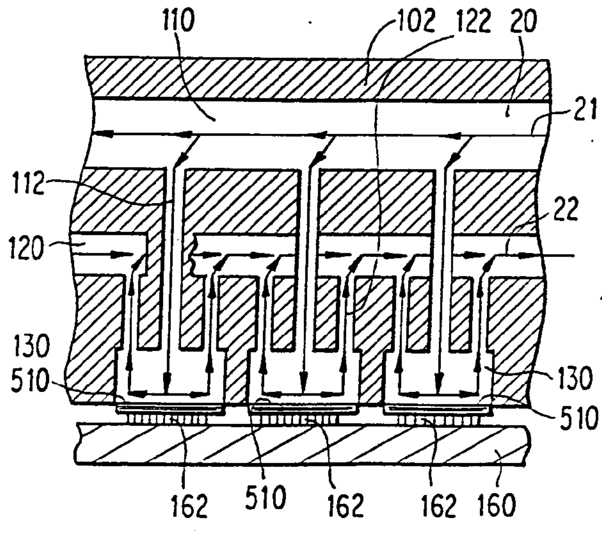


FIG. 3

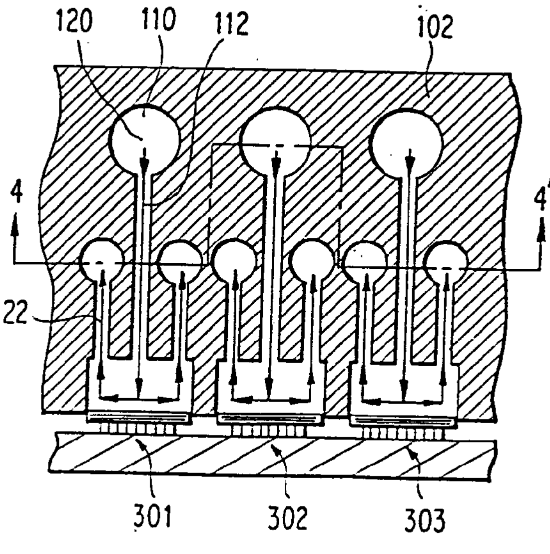


FIG. 5

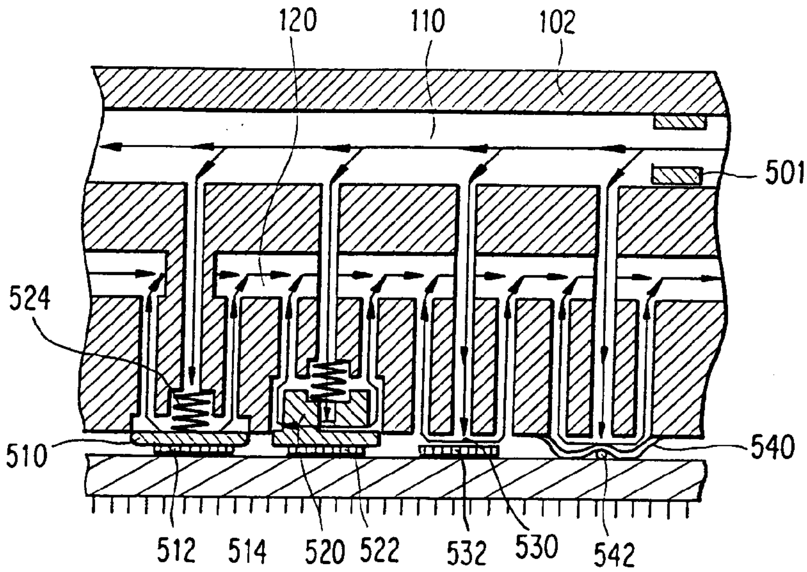


FIG. 6a

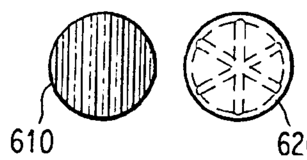


FIG. 6b

FIG. 7

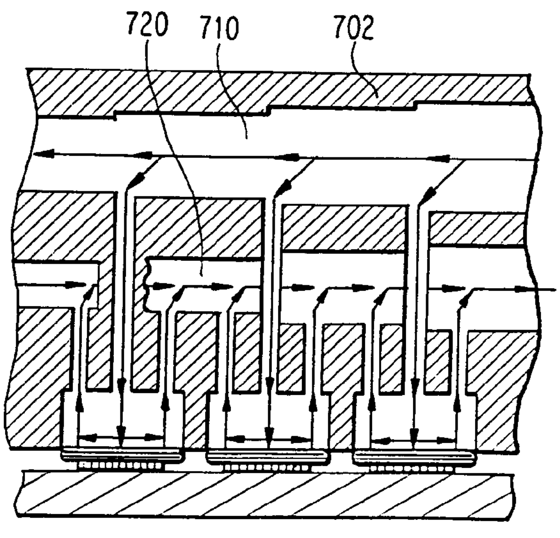


FIG. 8